Shallow-Water Reverberation

Ji-Xun Zhou
School of Mechanical Engineering, Georgia Institute of Technology
Atlanta, GA 30332-0405
phone: (404) 894-6793 fax: (404) 894-7790 email: jixun.zhou@me.gatech.edu

Award Number: N00014-97-1-0170

LONG-TERM GOALS

The long-term goals of this work are: to develop a practical model for predicting reverberation level (RL), echo-reverberation ratio and reverberation vertical coherence (RVC) in shallow water with sand and/or silt seabeds; to characterize seabottom geoacoustic parameters (sound speed and attenuation) and bottom scattering using high quality reverberation data in a frequency range of 100-3000Hz, and to reveal the physics of bottom scattering through analysis of shallow-water reverberation data.

OBJECTIVES

The scientific objectives of this year's research include: (1) To set up a quality data base of RL and RVC in a frequency range of 100-3000Hz. (2) To analyze the effects of seabed acoustic parameters, scattering models and sea surface on the RL and RVC. (3) To search for a suitable seabed geo-acoustic model to predict low-frequency reverberation and bottom scattering.

APPROACH

Ocean acoustics is an observationally driven science. As benchmark cases for theoretical modeling, quality at-sea reverberation data are extremely important. To develop a practical prediction model for reverberation, develop a seabottom scattering model, or to invert seabottom scattering strength and other seabottom acoustic parameters from reverberation, requires a reliable reverberation database either for comparison or validation. The measurement of quality reverberation data is a delicate task that can often be subject to errors. Wideband reverberation measurements were conducted at the ASAEX site, the Yellow Sea '96 site and other sites with flat and sand/silt seabed, using wideband explosive sources and a vertical hydrophone array. A quality reverberation data base obtained from these measurements will be used for data-model comparisons.

Shallow-water reverberation involves scattering from the seabed and surface as well as two-way sound propagation that is controlled by the seabed. Thus, both the seabed/surface scattering function and the seabed geo-acoustic model simultaneously control reverberation characteristics, and these two effects can be difficult to separate. Careful data-model comparisons on reverberation and one-way sound propagation at the same sites may be used to distinguish their effects.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2006**	2. REPORT TYPE	3. DATES COVERED **00-00-2006 to 00-00-2006**

4. TITLE AND SUBTITLE **Shallow-Water Reverberation**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Georgia Institute of Technology,School of Mechanical Engineering,Atlanta,GA,30332**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

RESULTS

(1) A quality wideband data base of RL and RVC, obtained from 3 "natural laboratories" in shallow water, has been set up. A natural laboratory is an experimental site with relative simple environment conditions: low sea state, nearly range independent water depth and seabed property. The data offer a basis for data-model comparisons on RL, RVC, reverberation-based seabed geo-acoustic inversion as well as the seabed scattering.

(2) Data-model comparison shows that, in order to characterize the seabottom scattering from reverberation data, it is critical to have ground-truth measurements of sound speed and attenuation in sediments at a given experimental site. With identical density and sound speed, but different acoustic attenuation in the sediments, numerical examples show that the Lommel-Seeliger law ($BS1 = \mu_1 \sin\theta$) and Lambert law ($BS2 = \mu_2 \sin^2\theta$) would result in very similar RL curves (vs. time). Thus, the reverberation-derived seabed scattering strength can easily be mixed up with uncertainty over seabed geo-acoustic parameters. Because of this, research on SW reverberation and bottom scattering requires a reliable seabed geo-acoustic model. A current research task is to identify a suitable geo-acoustic model at low frequencies. Low-frequency field measurements, conducted at 17 locations with sand and silt seabeds in different coastal zones around the world are currently being analyzed for this purpose.

(3) Possible effects of the sea surface on RL, RVC and RVC-inverted seabed reflection loss have been analyzed. This was done using wideband reverberation measurements that were made at a fixed location in the East China Sea on June 3rd and 5th, 2001 using the same measurement system. Sound-speed profiles were similar during both measurements. Wind speed (W) and RMS surface-wave height (σ) changed from 2.74 *m/s* and 0.10 *m* on June 3rd to 7.45 *m/s* and 0.33 *m* on June 5th (See Figure 1). Thus, these measurements offer an opportunity to evaluate sea-surface effects on RL, RVC and RVC-inverted bottom acoustic parameters in shallow water. The two sets of RVC and RL data, in a frequency range of 100-2500 *Hz*, show differences that are the apparent effects of the surface roughness. With increasing sea state, the RVC increases and the RL decreases. The effective bottom losses, inverted from the RVC data, correspond to the variation of sea state (see Figure 2). This additional loss gives a physical explanation of the characteristics of both the measured RVC and RL. The findings show the importance of surface effects in shallow-water reverberation and propagation models. These effects would be pronounced for high frequencies and sea states. For two cases we reported, the effects were most apparent for $f > 500 Hz$ when $W = 7.45$ *m/s*.

Figure 2 shows the difference of the effective bottom loss factors, inverted from the RVC measurements on June 3rd and 5th, 2001. The predicted seabed losses for June 5th shown in Fig. 2 are based on the earlier measurements on June 3rd and the known wind speed. The predictions are calculated from the Neumann-Pierson (NP) spectrum and the Pierson-Moskowitz (PM) spectrum. Figure 2 shows that the combined bottom and surface losses, inverted from the RVC measurements on June 5th, are in a range predicted by the NP and PM surface spectra.

PUBLICATIONS

1. J.X. Zhou and X.Z. Zhang, "Shallow-water reverberation level: measurement techniques and initial reference values," IEEE J. Ocean Eng. **30**, 832-842 (2005).

2. J.X. Zhou and X. Z. Zhang, "Broadband sound velocity and attenuation in sandy seabottom in shallow water," J. Acoust. Soc. Am., **119,** 3447 (2006).

3. L. Wan, J.X. Zhou and P.H. Rogers, "Comparison of transmission loss data with predictions based on inverted seabed parameters from the Yellow Sea '96 experiment," J. Acoust. Soc. Am., 119, 3226 (2006).

4. J. Yang, J.X. Zhou and P.H. Rogers, "Effect of wind-generated surface waves on vertical coherence of sound propagation in the East China Sea," J. Acoust. Soc. Am., **119,** 33346 (2006).

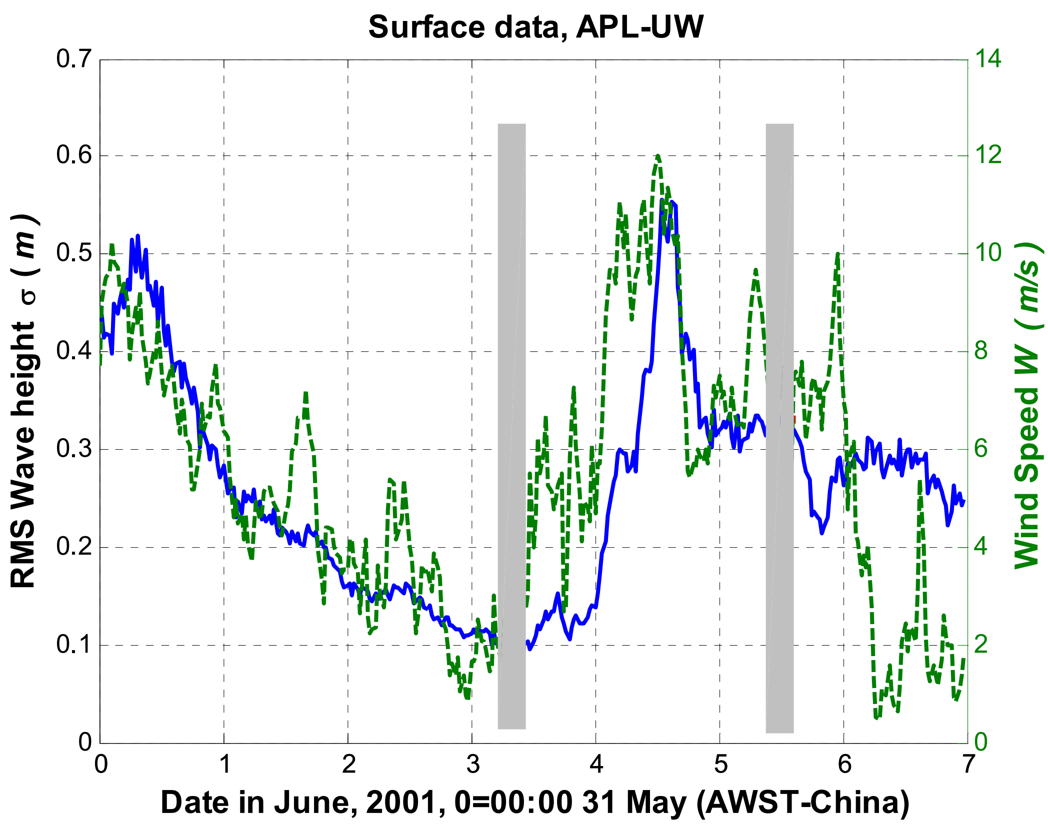

Figure 1 A 7-day history of the RMS surface wave height σ and the wind speed W. During two reverberation measurements, wind speed (W) and RMS surface-wave height (σ) changed from 2.74 m/s and 0.10 m on June 3rd to 7.45 m/s and 0.33 m on June 5th. The two time windows for reverberation data/model comparisons are marked with bars.

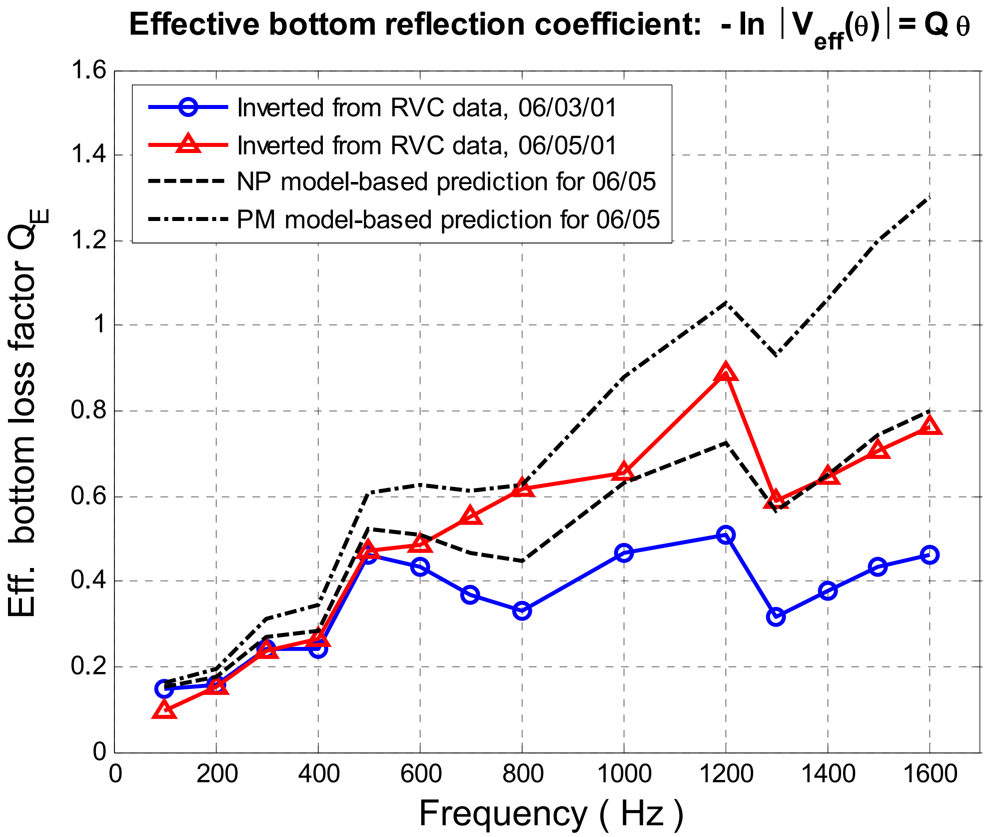

Figure 2 Comparison of the RVC-inverted effective seabed loss factor on June 5th with the predictions from the Neumann-Pierson (NP) spectrum and the Pierson-Moskowitz (PM) spectrum.